ملخص مادة..

قياسات ونواقل

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* Measurment : text book; Measurment and instrumentation Principle 3rd edition.

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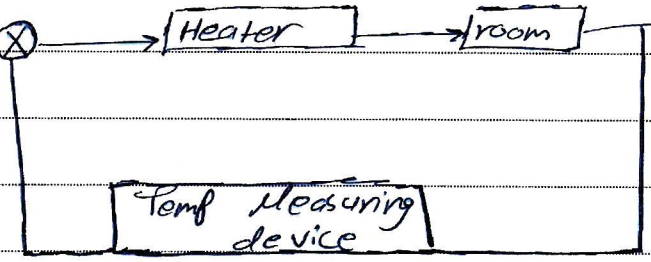
* chapter 1 ; Introduction ;

From the Beging of humman being For exchanging goo

* Recently , Measurments are very important since the inclustrial revolution.
* Major challenge is to produce accurate & cheap Measuring device.
* Measuring Units ; ① SI Units ; (kg, m, s)
② Imperial Units (ft, lb, s)

- derived Units : velocity m/s
density kg/m^3
Force N $\frac{kg\ m}{s^2}$

* Measurment system Applications ;
① Regluation tracle
② Monitoring Function
③ Using it as apart of the Feedback Like: وَلَا تَقْرَبُوا ; and Like :



Simple temp control sys
Heater will ~~Modify~~
Modify room Temp until Ta = Tcl

* Element of measurment S/S;

- measarment S/S may contains one or more of the Following; ① sensor ; Gives an output ; Like (Mercury in glass thermometer)

② variable conversion element ; Like the bridge circuit , which gives the displacement ,in the strain gauge as change converted to voltage . some times is called "transducer"

aim → improve the quality of the output signal.

③ Signal processing element , Like ; the electrical amplifier ④ Signal transmission.

⑤ signal presentation or recording.

---

* Choosing appropriate Measuring instrument ;

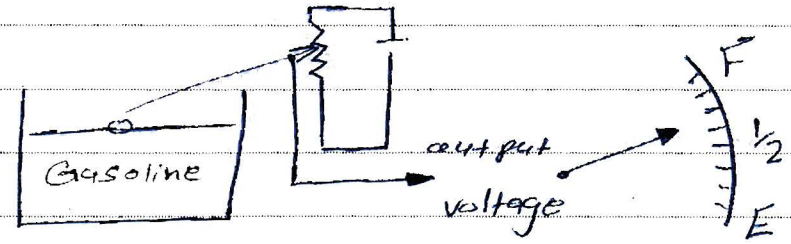
- we should choose the appropriate instrument according to the desired measurment accuracy resolution and sensitivity
- we need skilled engineers having good knowledge , to deal with the instrument.
- Refer to published Litrature to choose the suitable instrument data & specifications are available.
- cost is very important , need & budgets running cost and maintainance.

*chapter 2; Instruments types & performance characteristic.

- Two important types; ① active. , ② passive.

① Active instrument; The measured quantity is usually translated as electrical signal, some other times it is translated as pnematic or hydrolic.

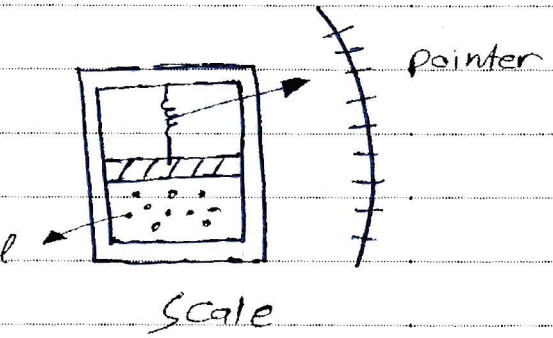
Ex:



② passive instrument; Direct measuring for the measured quantity.

Ex; pressure measuring device.

The passive instruments are very simple and direct as compared to the active instruments.



* Null type and deflection type instruments;

- Null type: usually dead-weight are used to balance the pressure.

- Deflection type; usually pointers are used to read the needed measure.

* Analeague and Digital instruments;

- Analogue; Continous output as quantity being measured (pressure gage using pointers)

- Digital; The output varies in descrete steps & can only have Finite no. of value.

* Smarts and non Smarts instrument;

Smart; any instrument has micro processor.

* Static characterisic of instruments;

- Accuracy; accuracy is measare of how close the output reading of the instruments is to the correct value.
- Inaccuracy; is the extent to which a reading might be wrong.

-usually taken as percentage of the Full scale of the reading of the instrument.

Full scale; highest value - lowest value.

Ex; for pressure gage of Full scale From (0-10) bar has quated inaccuracy ± 1% F.S (Full scale).

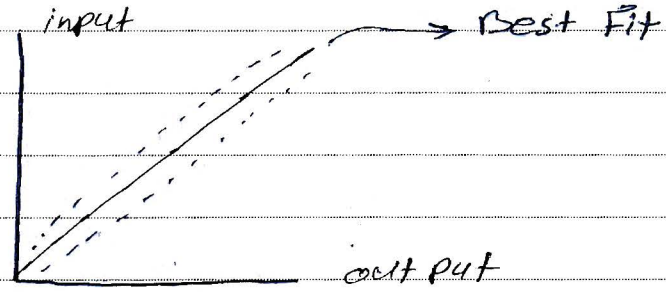
* inaccuracy value = $\pm \frac{1}{100} \times 10 = 0.1$ bar.

* 1 bar = 10^5 Pa. *

- sometimes we used the term (uncertinity) instead of (inaccuracy).

* Precision ; It describes an instrument degree of Freedom from random error.
it means that for Large no. of readings taken with the same quantity are very near To each other.
- Does a precise instrument mean it is accurate .
Not true all the time.
* Repeatability ; It describes the closeness of the output readings when same input is applied .
it is almost the same as precision .

* Range or span ; Minimum and maximum value of the quantity that the instrument is designed to measure .
* Linearity ; The output readings of the instrument is proportional to the quantity being measured .



output و input جميع ال
يتغيرا خطيا .

* Accuracy : how measurments output close to correct value.

Inaccuracy + accuracy = 100 %

precision; describes degree of freedom from ranelom errors.

= Large no. of readings are almost the same.

Does a percise instrument an accurate one ?

Not true all time.

~~Real~~ Repeatability ; is the same as precision.

---

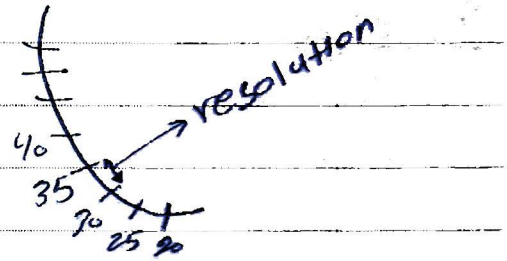
* Threshold ; minmum Level of input needed for measurable output.

Ex; for car speedometer usually the threshold is 15 km/hr

This means that any speed below 15 km/hr not readable.

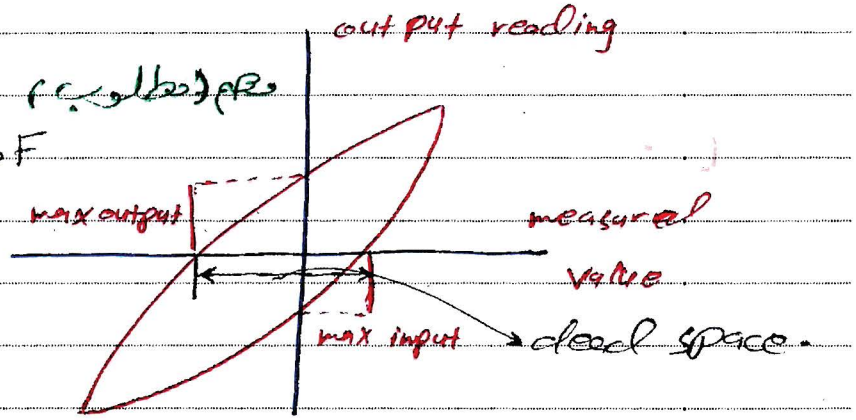
* Resolution; The absolute value or percentage value of the F.S (Full scale) deflection , some times it's is the subdevision of the scale.

threshold = 20 km/hr



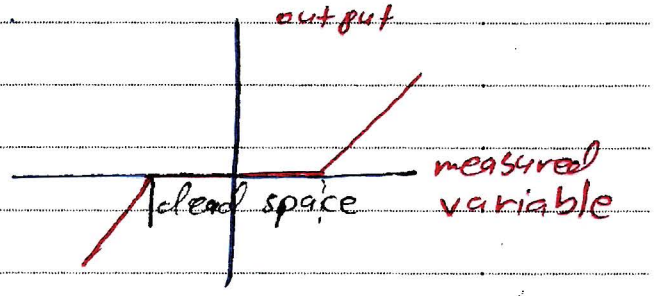
* Sensitivity to Distribution; This is mainly due to change of weather condition. (Ambient condition)
* Zero Drift or bias; describes the effect where the zero reading of an instrument is Modified by change in ambient conditions.
* Ex 2.2; * home work. *

* Hysteresis effect; The non-coincidance between Loading & unloading curve



* Dead space; range of different input values over which there is no change in the output value.
with input = No output
وهنا نحتاج لمعايرة الجهاز.

* Dynamic Characteristics of instruments;
it's a measure of the instrument which describes it's behaviour between the time a measured quantity changes value at the time when the instrument output attains (get) a steady value of responce.



→ Dynamic Characteristics of instruments;

① Zero order instruments; $a_0 q_0 = b_0 q_i$

a_0, b_0 ; const (o: out, i: input) ↳ coefficient

$q_0 = \frac{b_0 q_i}{a_0} = K q_i$ → K; is the instrument sensitivity

$K = \frac{b_0}{a_0}$

② First order instrument ;

if all coefficients $a_0 \dots a_n$ are assumed zero except for a_0 and a_1

$a_1 \frac{dq_0}{dt} + a_0 q_0 = b_0 q_i$

$a_1 D q_0 + a_0 q_0 = b_0 q_i \rightarrow q_0 = \frac{(b_0/a_0) q_i}{[1 + (\frac{a_1}{a_0})D]}$

$\tau = a_1/a_0$, $K = b_0/a_0$

τ; is the time const.

$$q_0 = \frac{K q_i}{1 + \tau D}$$

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Ex ; 2.3 : Altitude measuring is zero order (the change in input & output is Linear)
Temp change is First order.
time constant $\tau = 15s$
Temp at the ground is 10°c and Temp T_x at altitude of x meter is given by

$T_x = T_o - 0.01x$, $T_o = 10°C$

→ released at time zero, rise with velocity 5m/s

a) what is Temp at 10s intervals? up to 50 s

b) what is Temp, when altitude is 5000m.

Temp at general time t is $T_r = \frac{T_x}{1+\tau D} = \frac{T_o - 0.01x}{1+15D}$

$= \frac{10 - 0.01x}{1+15D}$

Velocity of Ballon $= \frac{dx}{dt} = 5 \rightarrow x = 5t$

$T_r = \frac{10 - 0.01(5t)}{1+15D}$

This equation has two solutions ; 1- integral (transciant "particular") , 2- complementy

① $T_{rcf} = Ce^{-t/\tau} = Ce^{-t/15}$

complemantary solution ← complemantary Function.

② $T_{rparticular} = 10 - 0.05(t-\tau)$ → particular solution.

→ complete solution = $T_{rcf} + T_{rpi}$

Total solution ; $= Ce^{-t/15} + 10 - 0.05(t-15) = T_r$

Find c From initial condition of time.

at $t=0 \longrightarrow Tr = 10 = c e^{0/15} + 10 - 0.05(0-15)$

$c = -0.75$

initial condition → released at zero time.

→ At altitude 5000m, time = 1000s

5m = 1s

5000 = 1000s

So, $Tr = -0.75 e^{-1000/15} + 10 - (0.05(1000-15))$

يمكن اهمالها

$Tr = -39.25\ ^\circ C$

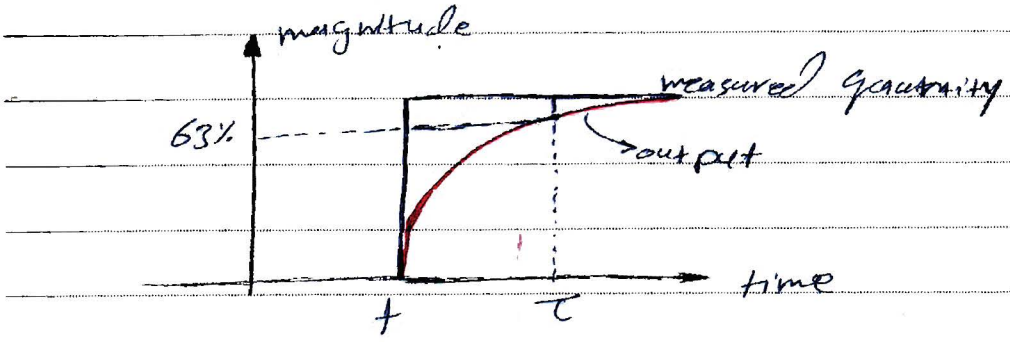
* Time constant has negligible value at the final answer from one term, but it has an effect from the second term.

time ; altitude Temp.

10 s
20 s
30 s
40 s
50 s

frame work.

* time constant ;



- The time constant τ of the step response is the time taken from the output quantity q_o to reach 63 % of the final value.

Q ; 2.9 ; Temp ⟷ depth

time const $\tau = 50$ s

at sea surface $T_o = 20^\circ C$

T_x at depth x is $T_x = T_o - 0.01x$

initial time = 0 , velocity 0.5 m/s $= \frac{dx}{dt} \rightarrow x = 0.5t$

→ Draw table of 100 s intervals up to 500 s, what is Temp at depth of 1000 m.

$\rightarrow T_r = \frac{T_o - 0.01x}{1 + \tau D} = 20 - 0.01 \times 0.5t$

$T_{rcf} = Ce^{-t/\tau} = Ce^{-t/50}$

$T_{rpi} = 20 - 0.005(t - 50)$

particular integral / $T_{total} = Ce^{-t/50} + 20 - 0.005(t - 50)$

initial condition at $t = 0 \rightarrow T_r = 20$

$20 = 20 + C \times 1 - 0.005(t - 50)$

$C = -0.25$

$T_r = 20 - 0,25 e^{-t/50} - 0,005(t - 50)$

this equation applicable for any time.

0,5 m → 1 s

1000 m → ?

needed time = 2000 s

at depth of F 1000 m

$T_r = 20 - 0,25 e^{-2000/50} - 0,005(2000 - 50)$

$= 10,25\ ^\circ C$.

note: initial condition الشروط الحركية.

boundary condition الشروط الهندسية

17/10 : chapter 3 ;

Errors during the measurment process ;

- Errors ⟶ during measurment
  - ↳ due to later correction of measurment
  - signal by induced noise. تشويش

* The errors heppend during measurment prcess are devided To :

a) systematic errors ; postive or negative in the output reading appears in one side of the correct reading either +ve or -ve.

b) Random errors ; +ve or -ve errors heppend due To unpredicted effects or factors.

* systematic source errors ;

- due to inherent factors in the manufacture of the instrument.

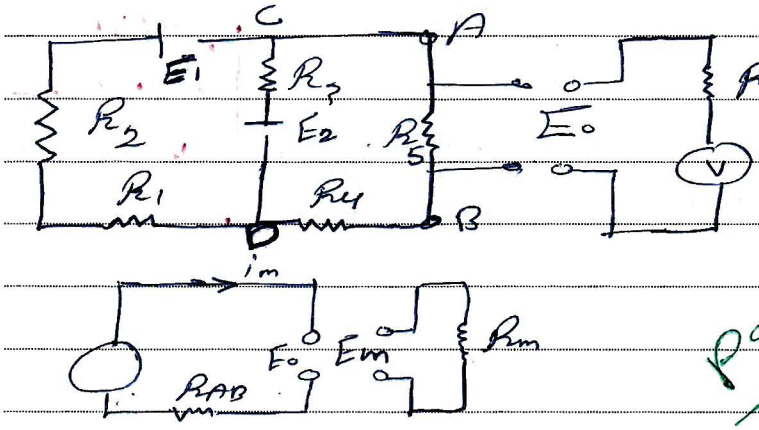
Ex ; vibrations are inherent effect for all rotating machines.

- إسباب تؤدي الى الاخطاء -

② Due To enviromental distcurbance;

③ Due To disturbance of The measarment sys by The act or process. of measarment.

✗ Measurment in electrical circuits;



page 35

$$R_{CD} = \frac{(R_1 + R_2)R_3}{R_1 + R_2 + R_3}$$

$$R_{AB} = \frac{(R_4 + R_{CD})R_5}{R_4 + R_{CD} + R_5}$$

Voltage measured

$$E_m = \frac{R_m E_o}{R_{AB} + R_m}$$

ratio of measured voltage to output voltage.

$$\frac{E_m}{E_o} = \frac{R_m}{R_{AB} + R_m}$$

Ex 3.1; for The same electrical circuit if $R_1 = 400\ \Omega$, $R_2 = 600\ \Omega$, $R_3 = 1000\ \Omega$, $R_4 = 500\ \Omega$, $R_5 = 1000\ \Omega$. if The internal resistance of the voltmeter $R_m = 9500\ \Omega$

what is The measured errors??

$$R_{AB} = \frac{\left(\frac{(R_1+R_2)R_3}{R_1+R_2+R_3} + R_4\right)R_5}{\frac{(R_1+R_2)R_3}{R_1+R_2+R_3} + R_4 + R_5}$$

$$= \frac{[(1000^2/3000) + 500]\,1000}{(1000^2/3000) + 500 + 1000} = 500\ \Omega$$

E_o: equivalent output voltage from the whole circuit.
E_m: given by the question as measured voltage.

$$\frac{E_m}{E_o} = \frac{R_m}{R_{AB}+R_m}$$ but measurment error $= (E_o - E_m)$

$$E_o - E_m = E_o\left(1 - \frac{R_m}{R_{AB}+R_m}\right) = E_o\left(1 - \frac{9500}{10000}\right)$$ (1)

$= 0.95 \times E_o$.

So 95% of the correct value is given.

and the error due to measured $= 100\% - 95\% = 5\%$

---

* Errors Due to enviromental input
* The magnitude of the enviromental induced variation is quantified by two constants. $\rightarrow a > 1$,
① sensitivity drift, ② Zero drift.
Both of them are induced in the specifications of the instrument.

---

* wear in the instrument component
- This happend after certain period of time the process of recalibration often periods is a full solution to this problem.

* Connectivity Leads ; The proplem of connecting The measuring instruments with varias parts create some times this kind of problem.

Reduction of systematic errors ;

① * carful instrument design

② * method of opposing inputs ; by (تعويض) compensates The effect of an enviromental input in measurment system by intraducing an equal and opposite enviroment input To cancel it.

"14/10"

③ High gain . Feedback .

④ Calibration

⑤ Manual correction of The output reading.

⑥ Intelligent instrument ; contains extra sensors to measure The value of enviromental input & automatically compensates The value of The output reading.

---

* Random erros ; caused by unpredicted variation This may be detected by :

① Statistical Analysis of measurment subjected to randoms errors.

$X_{mean} = \frac{x_1 + x_2 + \cdots x_n}{n}$ ← reading

$X_{median} = \frac{x_{n+1}}{2}$ ← reading in The middle of odd readings

اجمع واقسم على الأقل

The variance; $N = \frac{d_1^2 + d_2^2 + \dots d_n^2}{n-1}$

الإنحراف المعياري.

Standard Deviation; $\sigma = \sqrt{N} = \sqrt{\frac{d_1^2 + d_2^2 \dots + d_n^2}{n-1}}$

* solve The examples aFter this.

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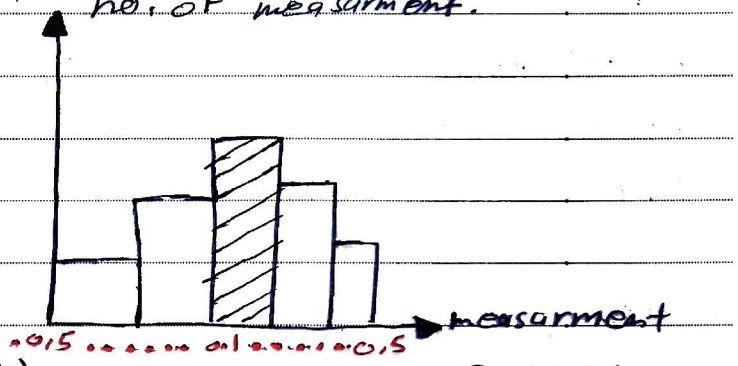
* Graphical data analysis techniques;

frequancy distribution

تردد المشاهدات.

والثاني هو الأكثر نسبة من المشاهدات.



11.8, 11.9, 12, 12.1, 12.6

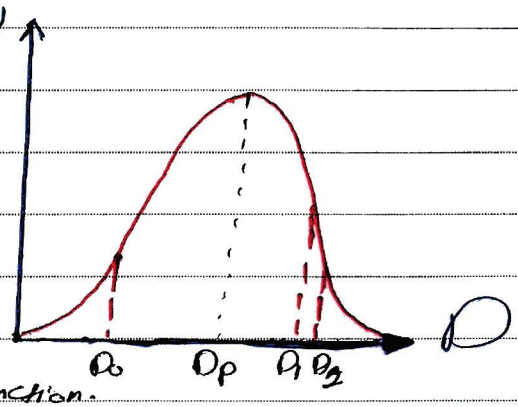
11.7, 11.6, 11.9, 12, 12.1

11.8, 11.9, 12.2 (الرقم القريب في الوسط)

* Most oF readings have very Little variation (Deviation). Some reading have more deviations, but there quantity is very Small.

The area under the curve is Unity.

Frequancy distribution curve oF Deviation where D.



D: Probability density Function.

the errors probability For any measurment Lies between Two levels D_1 , D_2

* If The distribution distance between D_1 & D_2 is larg → more errors.
* If The Distance between D_1 & D_2 is small → Less error.

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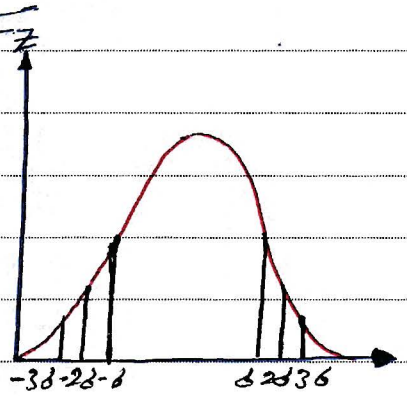
* Histogram graphs:
Gussian distribution useed For The random errors, it is defineed as a normalizeed Frequancy distribution that symmetrical about about line oF Zero errors.



$$F(x) = \frac{1}{\delta\sqrt{2\pi}} e^{[-(x-m)^2/2\sigma^2]}$$

x; no. oF data in the set (readings)
m; mean value.
δ; standard deviation.

$$F(D) = \frac{1}{\delta\sqrt{2\pi}} e^{-D^2/2\delta^2}$$

$Z = D/\delta$

F(-z) = is The area under The curve to The left oF (-z). it represents the propration oF the data IF -z

Page; 52: → accepted data → Not accepted

	data with boundary	out of boundary.
∓ 6	68%	32%
∓ 26	95.4%	4.6%
∓ 36	99.7%	0,3%

* Standard error of the mean $\alpha = \frac{\sigma}{\sqrt{n}}$
→ where n no. of readings.
* Any measurment value from a set of n readings can be expressed as $x = x_{mean} \pm \alpha$

Take case C in page 44, n = 23, σ = 1.88
mean = 406.5, median = 406.
→ Solve the Example for all cases.

$\alpha = \frac{1.88}{\sqrt{23}} = 0.39 \simeq 0.4$

Ex: If we have temp redings ... 19.9, 19.8, 19, 20.1, 20
Find median: 19, 19.8, 19.9, 20, 20.1 → median = 19.9 °c
→ 19, 19.7, 19.8, 19.9, 20, 20.1 → median = $\frac{19.8+19.9}{2}$ = 19.85 °c

∴ So the length can be expressed as 406.5 ± 0.4 with 68% confidance limit
By using 2σ = 3.76 leads to 2α = 0.78 } Table 3.1 p:51
→ 2σ = 95.4 confidance.

1.6 ; 0.9452
1.7 ; 0.9554 interpolation we find σ = 1.88 → 2σ = 3.76.

* mean, meadian, variance, σ, α * First الحاجات بالـ

→ For The accepted values in The boundary, ∓3.6 is The best with accepted values within The boundary. reduce 99.7 %, Then ∓2δ is accepted values up to 95.4 %, & The lowest accepted values Taken under The Range of δ with 68%.

* Note; ∓3δ, ∓2δ, ∓δ has nothing to do with standard deviation.

* Chapter "4" ... Calibration of measuring Sensors & instruments.

→ calibration consiste of Camparing The out put of The instrument or The sensor under test against an instrument of known accuracy.

→ Instrument used as standard in calibration process are usually chosen to be of greater inherent accuracy.

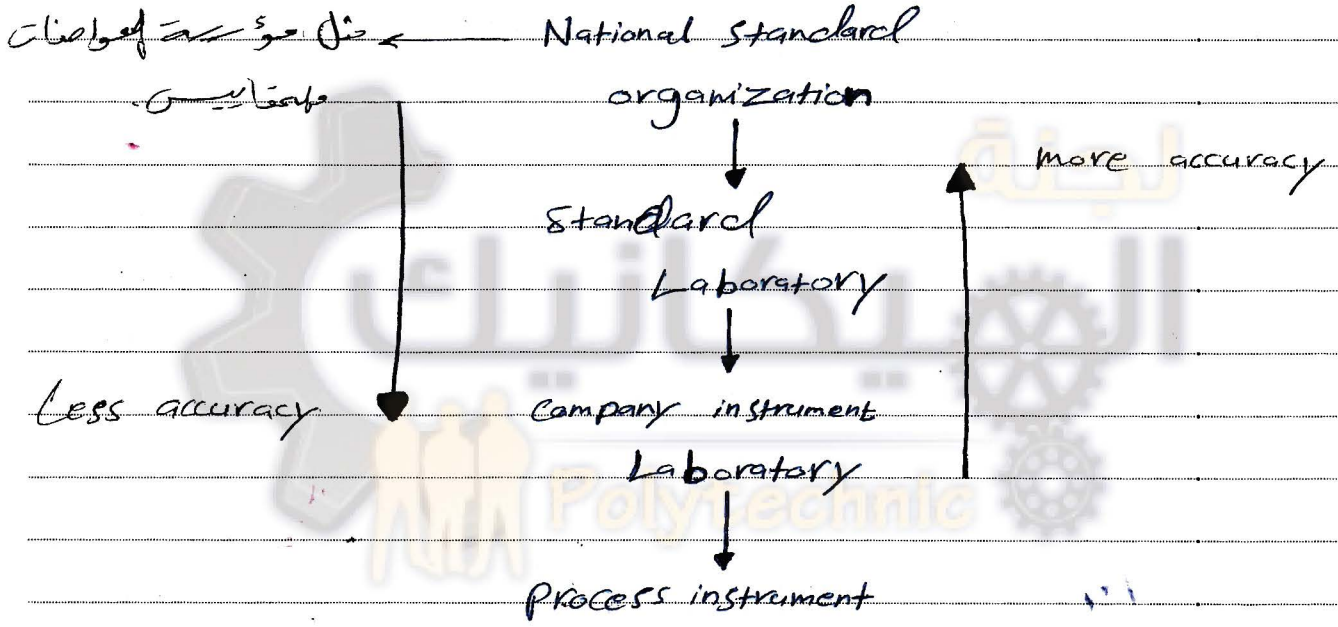
→ Frequancy of calibration depend usually on The needed accuracy of The instrument.

* Control of calibration enviroment:

→ instruments used For calibration as standard must be kept only for calibration duties لـ...

→ ISO 9000 ; international standard is controlling all calibration procedure For measurment to assame quality control.

→ All persons who do calibration process should be Trained.



ch 5

* Measurment noise & Signal processing;

noise source → measarment of circuit it self.
↳ During the transmsion of the signal.

Signal to noise ratio ; 20 Log $\frac{V_s}{V_n}$

V_s; mean voltage level of signal

V_n; mean voltage level of noise.

→ Induction coupling;

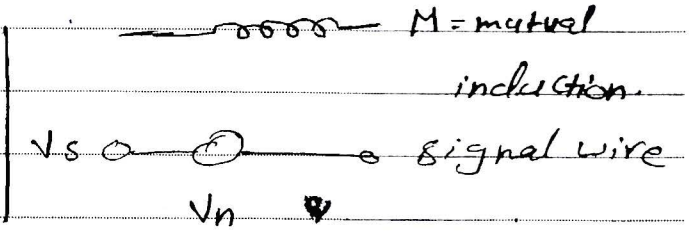
Flourescent Lighting and circuit working with audio or radio Freqauncy.

$V_n = MI$

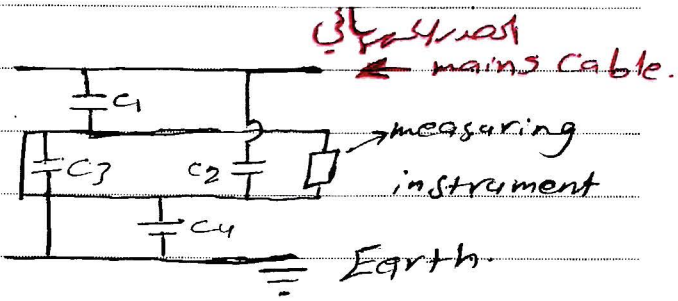
متبادلي

M = mutual induction.

Capacitance or Capacitive coupling



Noise Due To Multible earthes;

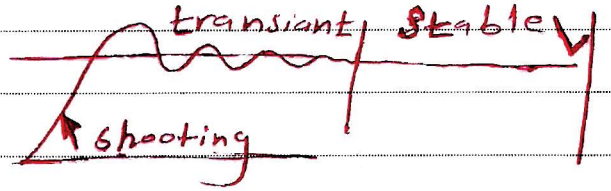


If $C_1 = C_2$

$C_3 = C_4$

$V_n = 0$

* Different machines with large currents are conected To The same earth plane will cause Noise To multible earth.
* Noise in The Form oF voltage transiant (spikes) due To swithing motors on & oF.F.



* Thermoelectric potetial → Thermal emf (elelctro motive Force) is Generated due To diFFerent conected metals. causing Thermoelectric eFFect.

* Shot noise.
* Electro chemical potential.

* Techniques For reducing measurment noise;
① Location & Design oF signal wires; The noise due To inductive & capacitive cupling can be mimized by inserting that signal wires by making them as far as possible From noise source, seperated oF 0.3 m is minimum 1 m is preFerable.
② Earthing; By Keeping signal wires & earthes For high current well earthed.

③ By enclosing wires in an earthed metal shields.

en: تغلب/كلمة فعل.

* Introduction To signal processing;

→ signal process improves the quality of The reading at The output of The measurment sys.

→ In The past signall processing done by analogue Techniques, Now it is done by digital Techniques are efficient.

* Analogue Signal Filtering;

→ The aim is to remove the certain band of Frequancy

Fig 5.4 page "80"
Fig 5.5 page "81"

→ Low-pass Filters (Remove Low Frequancy)

→ high-pass Filters (Remove high Frequancy)

→ banel-pass Filters (can remove Full bands of unwanted Frequancies)

→ band stop Filters.

* Passive Analogue Filters;

→ circuits that consists of only resistors & capacitors.

→ The problem is only mild Filtering effect can be achieved.

*Passive Analogue Filters:

- circuits that consist of ... pervious Lecture.

Z: impedence:

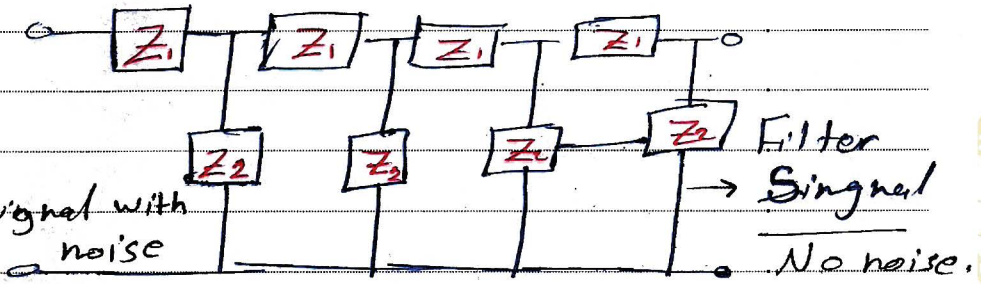


Fig 5.6

Simple passive analogue

*Z_1 & Z_2 are impedences

*Z_1 & Z_2 should be either pure capacitance or pure inductances with zero resistance, by this we insure that no dissipation of energy in that Filters.

→ see Fig 5.6.

*problem in passive Analogue Filters;

① it's difficult to obtain resistance ~~less in~~ is very low or very low resistance.

② The inductors are bulky (heavy, huge) → same mean.

*Active Analogue Filters;

- The use of active analogue Filters has overcome the problems of passive Filters.

- The major component in the active analogue filters are "Electronic Amplifiers"
- There is no inductors, only resistance & capacitors.

---

* Another Analogue signal processing;

1. Signal Amplification
2. Signal Attenuation
3. Differential amplification.
4. Signal linearization
5. Bias (zero drift) removal
6. Signal integration
7. Voltage Follower (pre-amplifier)
8. Voltage comparator
9. Phase-sensitive detector
10. Lock-in amplifier.
11. signal addition.
12. signal amplification.

إسمح تبعهم غير مطلوب

*ch:6

*Electrical indicating & test instruments

→ Digital meters ; all There types are developed From digital voltmeter (DVM)

→ The digital meters have the advantage oF ;

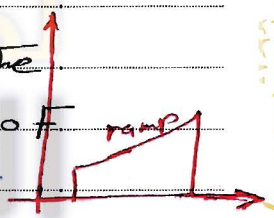
① high measurment accuracy

② Faster speed oF response to voltage change

→ The disadvantages ; high cost as compared to analogue instruments.

- Types oF DVM ;

① Voltage to time conversion (DVM) , This is The simplest Form oF DVM & is ramp type oF instrument (inaccuracy ± 0.05 %)



② potentiometer DVM ; This is using a servo principle [error between input voltage Level & areference voltage is applied to a servo drevin potentiometer That adjust The reference voltage until it balances the unknown voltage].

③ Digital slope integration DVM Simple & has better noise rejection capabilites (inaccuracy [± 0.005 %.]

---

④ voltage to Freqauney conversion DVM , main advantage is The ability To reject Ac noise.

⑤ Digital Multimeter ; it able to measure both Ac & Dc Signals over a wide range oF voltage & current.

* Analogue meter ;

→ advantages ; ① very simple compared to digital meter.

② Inexpensive compared to digital meter

→ They are usually passive instruments & They Don't need Power supply.

→ They are electromechanical devises that drive a pointer against a scale.

→ Inaccuracy Ranges from (∓0.1 % – 3%).

وهي بتكون عالية بسبب إضافات إلكترونية.

* Examples From The type of analogue meters ;

① moving coil meters ; very common used with good accuracy & Linear scale.

- Theoritical torque produced ;

$T = BIhwN$

B ; Flux density

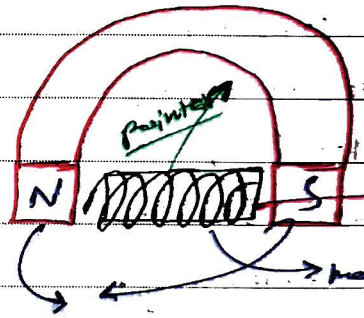
I ; current

h ; height of Coil

w ; width of Coil

N ; Number of winds

اللفات.



How it works شغل إزاي

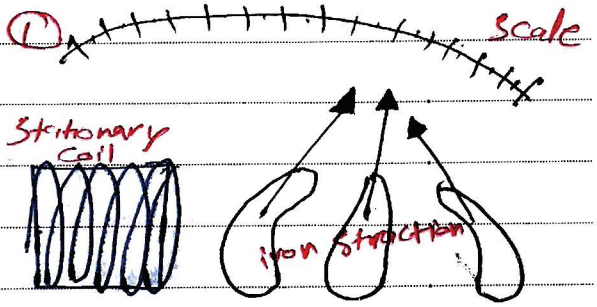
Rotation of The pointer is because the indicator between The induced Field of The coil & The Field produced by The permenent magnet.

② Moving iron-meter;

→ mainly For dc signal.

- can measure ac signal at Frequancy up to 125 Hz.

- Common use For voltage measurment.



- يتغير موضع العقلبا الحديدي حسب المجال المحتاطيسي.

How it works; مبدأ العمل

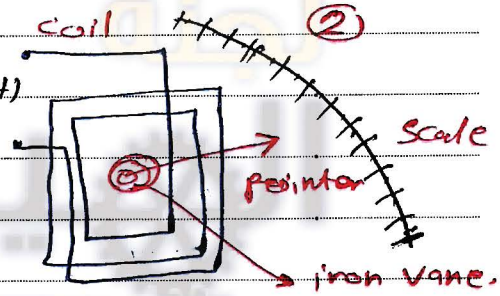
The signal To be measureed is applieed To the Stationary coil, The associateed Field produceed amplifieed by The presence of iron structure associated with The Fixeed coil.

عزم الدوران

$$T = \frac{I^2 \, d\mu}{2 \, d\theta}$$

μ → mutal inductance (H) Henry

θ → angle deFlection (rad)



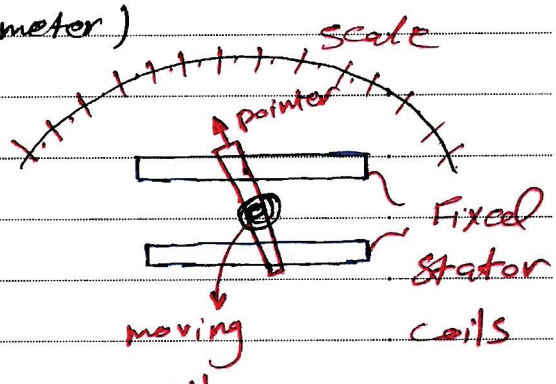
range For dc → up to 300 V

" " ac → up to 200 V

③ Electrodynamic meter (dynamometer)

The instrument has a moving coil That is mounted in The magnatic Field produced by two seperately wound circular Stator coils.

- Can measure ac & dc with max Frequancy up to 2K Hz,



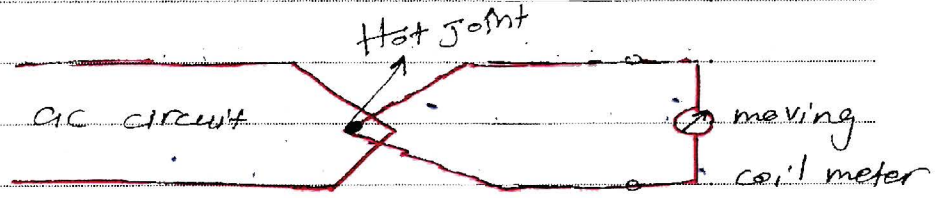
$$T = I_1 I_2 \frac{d\mu}{d\theta}$$

(4) clamp-on-meter
used for measuring circuits currents and voltage in a non invasive manner that avoids having a break in the circuit being measured.

(5) Analogue Multimeter: it is used for measuring of current, voltage, resistance & for both ac & dc signals

(6) Measuring high Frequancy signals:-
This is done by rectifying the voltage signal and the applying it to a moving coil meter, By this we can measured Frequancy up to 20 kHz.

* Thermocouple meter; The measures ac voltage signal is applied to a small element This heat up, and the resulting Temfareture rise is measured By a thermocouple The dc voltage generated in the Thermocouple is applied to a moving coil meter.
→ By This method, very high Frequancy up to 50 MHz can be measured.



ch 7; variable conversion element;

→ This is basically for the instruments with non voltage output form.

→ Using Bridge circuits are important type of variable conversion elements.

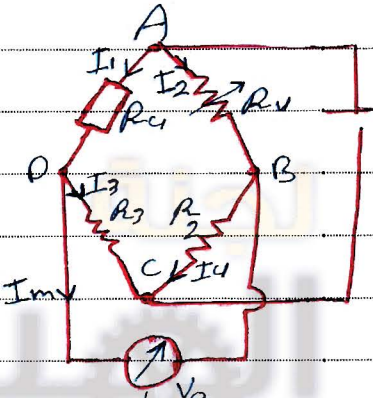
* Bridge circuits :-

① Null-type dc Bridge (wheatstone Bridge)

u; unknown, v; variable, m; measured

$I_1 = I_3$, $I_2 = I_4$, i; input

Rv; Keep changing it until voltage across Galvanometer = zero.



$$V_o = 0 = \frac{V_i R_u}{R_u + R_3} - \frac{V_i R_v}{R_v + R_2} \Rightarrow \frac{V_i R_u}{R_u R_3} = \frac{V_i R_v}{R_v + R_2}$$

$$R_u = \frac{R_3 R_v}{R_2}, \quad R_v = \frac{R_2 R_u}{R_3}$$

* القوانين حفظ.

→ high sensitivity Galvanometer.

② Deflection type dc. Bridge

The variable resistance "Rv" is replaceed by a Fixeed resistance "R_1" so; $V_o = V_i \left(\frac{R_u}{R_u + R_3} - \frac{R_1}{R_1 + R_3} \right)$

(بدل Rv بالمقاومة R_1 الثابتة.)

→ when $R_u = R_1$, Then $V_o = 0$ (geting baek to wheatston bridge)

Note: The v_o has positive or negtive value if $R_{eq} \neq R_1$
The changes of v_o are non Linear with the change in R_{eq}.

Ex; 7.1; (0-10) bar, $R_1 = R_2 = R_3 = 120\ \Omega$

$M = 10^6$, $m = 10^{-3}$

$V_i = I_1 (R_{eq} + R_3) = 0.03 (120 + 120) = 7.2\ V$

change For 1 bar is 0.338 Ω (For each bar).

maximum change for 10 bar is (3.38) Ω

So R_{eq} with the changes = 120 + 3.38 = 123.38 Ω

0.338 Ω ↑ أقصى تغيير / 0-10

→ Take for maximum value, for the wrost case.

$\therefore V_o = 7.2 \left(\frac{123.38}{123.38+120} - \frac{120}{120+120} \right)$

* from the previous information we can see the new voltage

$V_o' = V_i \left(\frac{R_{eq} + \delta R_{eq}}{R_{eq} + \delta R_{eq} + R_3} - \frac{R_1}{R_1 + R_2} \right)$

So $\delta v_o = V_o' - V_o = \left(\frac{V_i\ \delta R_{eq}}{R_{eq} + \delta R_{eq} + R_3} \right)$; if the change in R_{eq} is very small compared to the value of R_{eq} it self.

So $\frac{\delta v_o}{\delta R_{eq}} = \frac{V_i}{R_{eq} + R_3}$

Example: 7.2 when current taken by the measuring instrument is not negligible.

*: Ex; 7.3; wheatstone Bridge;

R_v has inaccuracy $\mp 0.2\%$

$R_3 = R_1 = 5000\Omega$ (مقاومة ثابتة) $\mp 0.1\%$

R_v at null position is $520.4\ \Omega$

what is the error band for R_u as percentage of it nominal value

/nominal means Given.

$R_v = 520.4 \mp 0.2\% = 521.44\ \Omega$

$R_3 = 5000 + 0.1\% = 5005\ \Omega$

$R_2 = 5000 - 0.1\% = 4995\ \Omega$

- 1st +

| → error band ←

$R_u = \frac{R_3 R_v}{R_2} = \frac{5005 \times 521.44}{4995} \times 100$

$= 522.48$ (R_v, R_u زاد)

Note that change in $R_u = \frac{522.48 - 520.4}{520.4} \times 100 = 0.4\%$

→ For Band of errors, take opposite signs for the next calculation;

Now we take the other signs for all values;

$R_v = 520.4 - 0.2\% = 519.36\ \Omega$

$R_3 = 5000 - 0.1\% = 4995\ \Omega$

$R_2 = 5000 + 0.1\% = 5005\ \Omega$

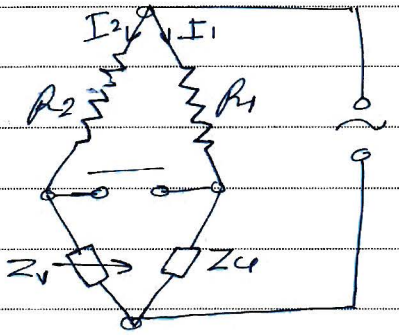
$R_u = \frac{4995 \times 519.36}{5005} = 518.32\ \Omega$

change in $R_u = \frac{518.32 - 520.4}{520.4} \times 100 = -0.4\%$

Note; same value for error should be appear.

→ Read Apex Balance. (self study)

A.c Bridges; it is used to measure unknown impedence



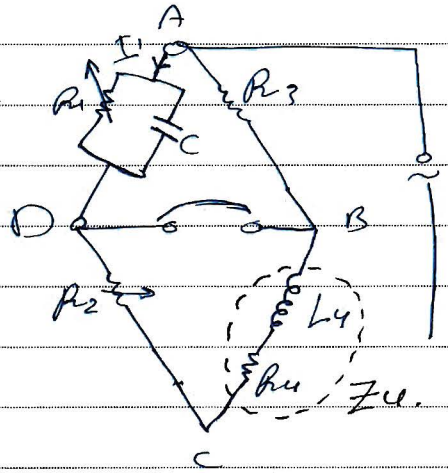
$I_1R_1 = I_2R_2$

$I_1Z_4 = I_2Z_v$

$Z_4 = \frac{Z_vR_1}{R_2}$

Maxwell Bridge

we have two variables resistance one standard Fixed value capacitance and one Fixed resistance.



$\frac{Z_{BC}}{Z_{AB}} = \frac{Z_{DC}}{Z_{AD}}$

$Z_{BC} = \frac{Z_{DC}Z_{AB}}{Z_{AD}}$ | unknown impedence

$R_4 = \frac{R_2R_3}{R_1}$ | unknown resistance

quality Factor of the circuit

$Q = Q\ value = \frac{\omega L_4}{R_4} = \frac{\omega R_2R_3CR_4}{R_2R_3} = \omega CR_1$

For case of constant Freqeuney

$Q \cong R_1$

$L_4 \leq R_2R_3C$

Ex; 7.5 , $R_3 = 5\,\Omega$, $C = 1\,mF$ | m; milli 10^{-3}
what is the unknown impedence(L_u, R_u) | μ; micro 10^{-6}
$R_1 = 159\,\Omega$, $R_2 = 10\,\Omega$ | M; mega 10^{6}

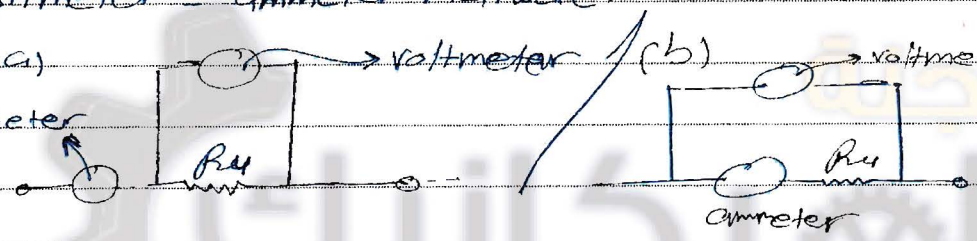
$$\rightarrow R_u = \frac{R_2 R_3}{R_1} = \frac{10 \times 5}{159} = 0.315\,\Omega$$

$$L_u = R_2 R_3 C = 10 \times 5 \times 1 \times 10^{-3} = 50\,mH \rightarrow \text{Hennry.}$$

16/11 ..

① D.c Bridge circuits ; best accuracy with null-output type of wheatson bridge with inaccuracy of a bout ± 0.02 %.

② Voltmeter - ammeter methacle.



In (a) ; The ammeter measures the current flowing in both voltmeter & resistance.

In (b) ; The voltmeter measures the voltage drop across the unknown resistance and ammeter.

→ inaccuracy a bout ± 1 %.

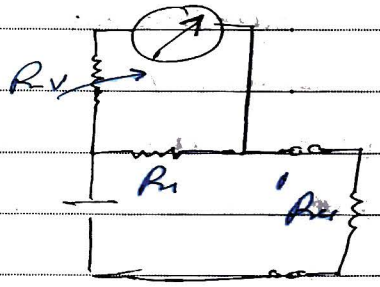
③ Resistance - Substitution methacl.

* The unknown resistance is replaced by variable resistence.

④ Using Digital Voltmeter to measure the resistance
→ The inaccuracy is very small ±0.1 %.

⑤ The ohmmeter; a battery applies a known voltage across a combination of unknown resistance & known resistance in series.

$$R_{x1} = R_1 \frac{(V_b - V_m)}{V_m}$$



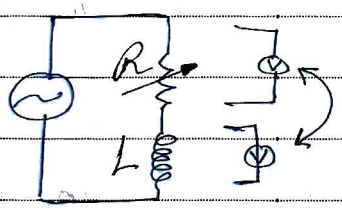
V_b; known battery voltage
V_m: measured voltage.
→ Range is from milli ohms — 50 MΩ
→ inaccuracy is 2 %.
→ worst method to find unknown resistance.

---

* Induction Measurment; as explained in the impedance measurment in Maxwell bridge, another approximated method by connecting the unknown inductance in series with variable resistance, so the voltage across the resistance will be equal to the voltage across the inductance.

R_1; value of variable resistance.

$$L = \frac{\sqrt{R^2 - r}}{2\pi f}$$



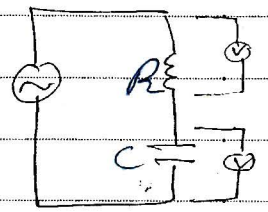
r; value of inductor resistance.
f; exition frequancy.

* Capacitive Measurment;

Same method as the one useed in the inductance

$C = \frac{Vr}{2\pi f R Vc}$ Vr; voltage across resistance.

Vc; voltage across capacitance.



* Current Measurment;

→ It is needed for many devices like Thermocouples - gauge pressure, ionization Gauge that have output in the form of varying electrical current.

→ need in the signeel transmition systems.

→ All types of analogue and digited voltmeters can measure the current.

* Freguancy Measurment;

→ Needed for all devices that converts the measureel physical quantity into freguaney change

→ variable relactance velocity transducer.

→ Stroboscope.

→ Vibrating wire force sensor.

→ resonant wire pressure sensor.

The frequency measurements can be done using one of following

1- Digital counter-timer
* very high accuracy, inaccuracy is very low upto 10^{-8}
* typical to measure 100kHz - 1MHz

2- Phase-locked up

3. Cathod ray oscilloscope

4. The Wine bridge

Phase measurement

Instrument that convert the measured variable into a phase change in a sinusoidal electrical signal, these instrument include

* transit-time ultrasonic flowmeter
* radar level sensor
* LVDT (linear variable differential transformer) it converts rectilinear motion into corresponding electrical signal.

Some methods for phase measurment

1- Electrafic Counter-timer
2. X-Y Plotter
3- Osdillosfope
4- Phase-sensitive detector

Chapter 13

Sensor Technologies

(1) * Capacitive and resistive sensors

* Capacitive sensor consists of two parallel metals plates in which the dielectric between the plates is either air or some other material $C = \frac{\epsilon_0 \epsilon_r A}{d}$

ϵ_0 is the absolute permittivity
ϵ_r = relative
A area of the plates
d distance between plates

Uses for displacement Sensors with fixed plate of the capacitor and a moving one.

* Resistive sensor: rely on the variation of the resistance of material when the measured variable is applied to it
Commonly applied for temperature measurement

(2) * Magnetic Sensor utilize the magnetic phenomena of inductance, reluctance and eddy currents to indicate the measured value

* Inductive sensors: translate the movement into change in the mutual inductance between magnatically coupled parts

* Variable reluctance sensors usually used for measuring rotor velocity, depending in the change of the magnatic flux.

* Eddy current sensor: to measure the displacement

(3) Hall-effect sensor

* device to measure the magnitude of the magnetic field
* it consists of a conductor with current that is aligned to magnetic field, this will produce voltage corresponding to the magnitude of the magnetic field

(4) Piezoelectric transducers → it produces voltage when a fore is applied to them, also used as ultrasonic receivers and displacement transducers

* They are also capb of measuring acceleration, pressure
* For rectangular block of material, the induced voltage is

$$V = (k f d)/A$$

k is piezo-electric const.
A ; area in mm^2
d thickness
F Fore

(5) Strain Gauge : they are devices that experience a change in resistance when they are stretched or strain, they are able to detect very small displacents in range of 0 - 50 μm

* inaccuracy in the range of ± 0.15%

(5) Piezoresistive Sensors: they are made from semiconductor material

* they are used as a strain gauge with better accuracy than the normal strain gauges, with inaccuracy of ±0.1%

(7) Optical sensor (air path)

* based on the modulation of light travelling between a light source and a light detector.

* They are used to measure proximity, translational motion, rotational motion and gas concentration.

(8) Optical sensors (fiber-optic)

* fiber optic is used instead of using air path

* The basic of the operation of fiber optic is the translation of the physical quantity measured into a change in one or more parameters of a light beam. like intensity, phase, polarization, wavelength, ...

* fiber-optic sensors usually incorporate either glass/plastic cables or all plastic cables.

* inaccuracy ±1% of full scale reading

أتوقع إجتهدت في مراجعتها

(9) Ultrasonic transducers

* This type of measurements are used for
  - fluid flow rate
  - liquid Level
  - translation displacements
  - imaging systems

* The device consists of one device that transmits an ultrasound waves and another device that receive the wave.

Relation between wavelength frequency and

wavelength ← $\lambda = v/f$ → velocity of wave

frequency of wave

عن مطلوب 13.9.6 ← 13.9.1 الفرع س

Measurement resolution and accuracy

* best measurement resolution is equal to wavelength of the transmitted wave

(10) Nuclear Sensor

Not commonly used because (i) safety regulations (ii) usually expensive

example: the use of Caesium-137 as gamma-ray source and sodium iodide used as gamma-ray detector

(11) Microsensors

advantages: (i) very small, (ii) improved performance (iii) Lower cost (Cheaper) (iv) better reliability

uses: temp, pressure, force, humidity magnetic field ---

material: mainly Silicon semiconductor material sometimes plastic, polymer, glass --- are used

Chapter 14

Temperature Measurement

* Temperature measurent is very important especially for process industry
* The "International Practical Temperature scale" IPTS has six fixed points

* Main priciples for temp measurents are
  - → Thermoelectric effect
  - → Resistance change
  - → Sensitivity of semiconductor devices
  - → Relative heat emission
  - Colour Change

Thermoelectric effect sensor (thermocouples)

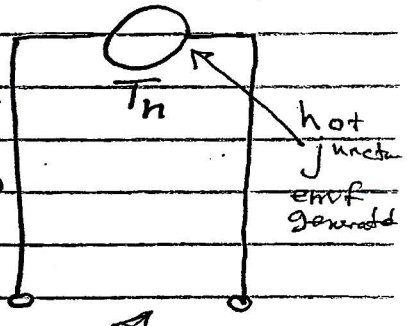
→ The Principle "when any two different metals are connected together, emf which is function of temperature is generated at the junction between the metals"

$$emf = e = e_1 T + a_2 T^2 + a_3 T^3 + \dots + a_n T^n$$

for certain materials $e \simeq a_1 T$

Practically several functions are used at hot junction, so the measured voltage is the summation of the used junction voltages

$$E_m = E_1 + E_2 + \dots$$



measured

14.1 + 14.2 Thermoc. انشاء

make interpolation

The second exam ;- 5, 6, 7, 13, 14 ...

* ch 14 ;-

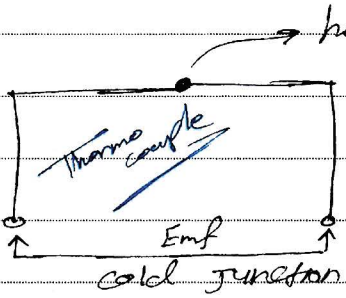
refer to Appendix "3" Types of Thermocouple.

Type E
Type J
Type K
Type N
Type S
Type T

Temp°c	Type E	Type J
	emf (m.v.)	emf (mv)
↑ 0°c ↓	↑ 0 ↓	↑ 0 ↓

emF: electro motive Force
mv ; milli volt
→ Zero reference.

Thermocouple ; For measure the Temp in difficult cases.



* change of emf with temp is Linear, & we must make interpolation in order to get the unknown temp.

Laws;

$emf = a_1 T + a_2 T^2 + \dots + a_n T^n$ → you can neglict these terms.

$Em = E_1 + E_2 + \dots$

*; Non Zero reference junction temp;

→ intermediate Temp

$$E(T_H, T_o) = E(T_H, T_r) + E(T_r, T_o)$$

where; T_H: Hot Junction Temp

T_o; Zero reference Junction

T_r; non-Zero reference Junction Temp (intermediate)

(سبائك) alloys

Ex; 14.3; (chromal - constantan)

at 80°c, emF_{output} = 40.102 mv

Find The Temp of The Fluid in which the hot Junction is immersed.

→ emF From intermediate junction and hot junction

T_r = 80°c, "$E(T_H, T_r)$" = 40.102 mv

From Tables; "$E(T_r, T_o)$"$|_{at\,80}$ = 4.983 mv

The Type is "E"; (emF → zero - intermediate Junction)

$$E_{total} = E_{(T_H, T_o)} = E_1 + E_2 = 40.102 + 4.983 = 45.085 \text{ mv}$$

E_{total} → From Tables, see the temp against "45.085" = 600°c

Ex; 14.4; chromal - Alumal (Type K); (12.1 emF)

T	emF
290	11.793
T	12.1
300	12.207

$$\frac{300 - T}{300 - 290} = \frac{12.207 - 12.1}{12.207 - 11.793}$$

∴ T = 297.4°C.

$V = 12.1 = E_1 + E_2 + E_3$

$E_1 = 12.1 - (E_2 + E_3) = 12.1 - E_2 - E_3$

على التركيبة الداخلية للثرمكابل Alumel - chromel

both of E_2 & E_3 are calculated at 40°c For Type "K"

$\longrightarrow E_1 = 12.1 - (-1.611) - (-1.611) = 15.32$ mV.

T	emf
370	15.132
T	15.32
380	15.552

$\longrightarrow T = 374.5$ °c

* Thermocouple Types:- P.280

$\longrightarrow$ All paragraph From "chromel - constanton" $\longrightarrow$ 1985

* كل الأرقام في هذا الجدول للقراءة فقط ...

Thermocouple Type	sensitivity	inaccuracy	Temp range
① chromel - constanton	highest	∓0.5%	-200 ∓900°c
	80 Mv/°c	[illegible]	-150°c - +1000
② Iron - constanton	60 Mv/oc	∓0,75%	-200°c - +750°c
③ Copper - constant	60 Mv/c	∓0,75%	
④ chromel - alumel	45 Mv/c	∓0,75%	+700 - +1200 °c
⑤ Nicrosil - nisil	40 Mv/c	∓0,75%	
⑥ platinum - rahdium	10 Mv/c	∓0,5%	+1500 °c
⑦ tungsten - rhenium	20 Mv/°c		2300°c

* Thermocouple protection:-

Sheath:-

→ To reduce the error which happened because of induced strain in the Hot junction.

→ It's usual to cover the thermocouple wire with Thermal insulation.

→ From the common sheath materials mild steel and other materials in Table 14.1

note: you have to know 4 of them. . احفظ 4 منهم!

① Thoria, ② special steel ③ Magnesia, ④ Zirconia

* Thermocouple manufacturing:-

→ welding is the most common technique used to connect two wires of different materials.

→ Diameter of wires used in the thermocouples range from 0.4 - 2 mm

The Thermopile;

→ By using several thermocouples connected in series to give better sensitivity.

→ 25 of Chromel-constantan thermocouple pile will Give resolution up to 0.001 °C.

Ch;16;- Pressure measurment;-

- Absolute pressure;- difference between the pressure of the Fluid and the absolute zero of pressure.
- Gauge pressure; Difference between the pressure of the Fluid and atmospheric pressure.

→ Absolute pr = Gauge pr + patm.

- Differential pressure;- Difference between 2- absolute pressure values.

→ in most applications, the range of pressure measured (1.013 - 7000 bar)

→ This range is "normal pressure range", and a large no. of sensors are available can measure pressure in this range.

→ The measurement outside this range are much less common.

*types of pressure sensors;-

note;- Measurments; - static pressure measurment; primarily concerned on it.

- Dynamic " " ; requires special instruments and very specialized area.

①; Diaphragms;-

- Different versions of diaphragms sensors can measure both absolut pressure (up to 50 bar), and gauge pressure (up to 200 bar), also can be used to measure Differential pressure (up to 2.5 bar).
- plastic diaphragms are cheapest.
- metal diaphragms Give Better accuracy.
- Stainless-steel used in high Temp or corrosive enviroments.
- Ceramic diaphragms are resistanec to strange acids and alkalis, and used when the operating enviroment is particularly harsh.

- The magnitude of diaphragms displacement is 0.1 mm
- other Forms of displacement measurment are used in some kinds of diaphragms based sensors.
- IF the displacement is measured with strain Gauges, it's normal to use 4 strain gauges arranged in a bridge circuit configuration.
- The output voltage From the bridge is a Function of the resistance change due to the strain in the diaphragms.
- and This arrangement automatically provides compensation for environmental Temp changes.

→ Fig (15.1) في page: 305.

- The difficulty of Bonding gauges to the diaphragms remained and new problem emerged regarding the highly non-linear characteristic of the strain-output Relationship.

→ This problem solved with the emergence of monolithic piezoresistive pressure transducers.

→ piezoresistive pressure transducers ; uncertainty (inaccuracy) is ±0.5 %.

→ instruments can offer automatic temp compensation, built in diagnostics and simple calibration procedure ; → inaccuracy reduced to: ±0.1 % of Full scale.

② Capacitive pressure sensor :

- a diaphragms device in which the diaphragms displacement is determined by measuring the capacitive change between the diaphragms and a metal plate that is close to it.

uncertainty ; ±0.2 %

③ Fibre-optic pressure sensors: provide an alternative methode of measuring displacements in diaphragms and Bourdon tube pressure sensors by optoelectronic means, and enable the resulting sensors to have lower mass and size compared with sensors in which the displacement is measured by other methods. → Fig (16.2) من الكتاب page 307.

④ Bellows: another elastic element type of pressure sensor that operates on very similar principles to the diaphragms pressure sensor.

- pressure changes within the Bellows, which is fabricated as seam-less tube of either metal or metal alloy, produce translational motion of the end of the bellows that can be measured by capacitive, inductive (LVDT) or potentiometric transducers.
- Different versions can measure either absolute pressure (up to 2.5 bar) or gauge pressure (up to 160 bar).

→ Double-bellows versions are exist and designed to measure differential pressure (up to 30 bar).

→ Bellows have inaccuracy: ±0.5%. → Fig (15.4) من الكتاب p.308.

⑤ Bourdon Tube:

→ elastic element type, → Cheap → commonly used for measuring gauge pressure of both gaseous and Fluid Liquids.

→ Flexible, metal tube. → Fig (15.5 p. 309) من الكتاب (بس)

* Three common shape of Bourdon tube:

C type / Spiral type / Helical type.

→ Maximum possible deflection of the free end of tube is proportional to the angle subtended by the arc through which the tube is Bent.

C type: max value For this arc is less than 360°.
- available to measure pressure (up to 600 bar)
- radius oF tube = 25 mm, has max displacement oF 4 mm
- inaccuracy: ± 1% oF Full scale deFlection.

Spiral; - max measure Pressure 700 bar.
and - inaccuracy similar to C type. (±1 %. oF Full scal.)
Helical - measurment resalution highe C type.
- when greater measurment sensitivity require, these types are used.

*note: The pointer oF Bourdon tubes is set at zero during manufacture, using air as calibration medium, but iF a different Fluid, especially a Ligquid is used with a Bourdon tube, the Fluid in tube will cause anon zero deFlection according to it's weight compared to air resulting in a reading error up to 6%.

~~//~~ * ⑥ Manometers: are passive instruments.

① U-tube manometer: - most common From oF manometer.
*P = hρg. / measure: Absolute, gage, DiFFerential.
- measure DiFFerential pressure according $P_1 - P_2 = h\rho g$.
- output reading subject to error.

How it work?: Applied pressure causes a displacement oF Lig. inside U-shaped tube, and output reading (P) is made by observing the diFFerence (h) between the level of Lig. in 2-halves oF the tube A and B.

gauge pressure measurement: IF an unknown pr is applied to side A, and side B is oped to atmospheric.

Absolute pr measurment: IF side B is sealed and evacuated.

- In absolute pr measurment, an addition error occures because it is impossible to totally evacuate the closed end of the tube.
- U-tube measure gauge & differential pr; up to about 2 bar.

② well tube or cistern manometer: similar to U-tube.
- The change in the level of the well as the measured pressure varies is negligible.
- The liq level in only one tube has to be measured, which makes the instrument much easier to use than U-tube.

→ If an unknown pr p_1 applied to port A, and port B is open to atmospheric, the Gauge pr given by $p_1 = hp$.

→ note: it might appear the instrument would give better accuracy than U-tube, because the need to subtract 2 liq level measurments in order to arrive at the pr value is avoided, However this advantage swamped by errors.

such variations don't affect the accuracy of U-tube to some extent.

③ Inclined or draft Gauge manometer:-

Similar comment about accuracy above.
- a variation on the well-type in which one leg is inclined to increase measurment sensitivity.

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Ch; 16:

* Flow measurment:-

*16.1; mass Flow rate:- Largely determined by whether the measured quantity is in a solid, Liq, or gaseous state.

*16.1.1; Conveyor-based methods:- This mode of transport allows the mass Flow rate to be calculated in term of the mass of material on a given length of conveyor multiplied by the speed of conveyor. → Fig 16.1 شوف

$Q = M v / L$; M; mess, L; Length, v; velocity, Q; mass Flow rate

*16.1.2; coriolis Flowmeter; used to measure the mass Flow rate of Liq, although it has also been successfully in some gas Flow measurment applications.

- The Flowmeter consists of either a pair of parallel vibrating tubes or else a single vibrating tube that is formed into a configuration that has 2 parallel sections.
- The vibratory motion of each tube causes forces on the particles in the Flowing Fluid.
- These Forces induce motion of the Fluid particles in a direction that is orthogonal to the direction of Flow, and this produce coriolis force.

→ coriolis meter Give excellent accuracy, with inaccuracy ±0.2%

*16.1.3; Thermal mass measurment:- Thermal mass Flowmeter used to measure the Flow rate of gases.

- The principle of operation is to direct the flowing material past a heated element.
- The mass flow rate is inferred in one of 2 ways;

a) By measuring The Temp rise in Flowing material
b) By " the heater power required to achieve constant Temp in Flowing material.
→ inaccuracy; ± 2 % (mass flow rate has better accuracy)

* 16.2; Volume flow rate:
* 16.2.1; Differential pressure (obstruction-type) meters; Involves the insertion of some device into a Fluid-carrying pipe that causes an obstruction & creates a pressure difference on either side of the device.
- Device use to obstruct the Flow include the orifice plate, the venturi tube, the Flow nozzle and Dall Flow tube.
- The velocity of the Fluid through the restriction increases & the pressure decrease.
- Measuring The 2- pressures with different instruments and calculating the difference between the 2-measurment is not satisfactory, because of the large measurment error.
* pitot static tube is a further device that measures Flow by creating a pressure difference within a Fluid carrying pipe
- The Annubar is a type of multi-port pitot tube that does measure the average flow across the cross section of the pipe by forming the mean value of several local Flow measurments across the cross section of the pipe.

→ Fig 16.3 كلمني

- Flow restriction type instruments are popular.
- Venturi tube can be used to measure the flow of dilute slurries.

equation 16.1: $Q = \left(\frac{A_2}{\sqrt{1-(A_2/A_1)^2}}\right)\left(\sqrt{\frac{2(p_1-p_2)}{\rho}}\right)$

orifice plate; (the wrost accuracy pressure)

- is metal disc with a concentric hole in it.
- simple, cheap, available in wide range of size.
- account for almost 50% of instruments used in industry
- inaccuracy at least ±2% and may reaches ±5%.
- wrost accuracy pressure loss (50 - 90%) of $(p_1 - p_2)$.

Venturi and similar Devices:-

- They are all much more expensive than orifice.
* The venturi has a precision-engineered tube of a special shape.
- This offers measurment uncertainty of ±1%.
- pressure loss (10 - 15%) of $(p_1 - p_2)$

* Why venturi has better accuracy than orifice?
- in venturi we have smoth reduction in the area, while in orifice we have sudden decrease in area, and drop in pressure more head loss.

Dall Flow tube; similar internal shape to venturi

except that it lacks a throat.
This construction much easier to manufacture, and this gives the Dall tube advantage in cost over venturi. / Dall tube is shorter Length.
- in accuracy; Little highe ±1.5% / (pr loss 5%) of $(p_1 - p_2)$

* Flow nozzle :- simpler construction.
- cheaper than Dall & venturi.
- pressure loss (30-50%) OF $(P_1 - P_2)$.

* Pitot Static tube :-
velocity; $V = \sqrt{2DP}$
- very useful where there is a requirement to measure Local Flow rates across the cross section OF a pipe, in case OF non uniform Flow.

* Advantages :- - negligible pressure loss in Flow.
- cheap.
- installation procedure very simple.

* inaccuracy; ± 5%, but more expensive versions can reduce inaccuracy to; ± 1%
So The inaccuracy is ±(1-5)%.

* 16.2.2 ; Variable area Flowmeters (Rotameters).
- variable aperture used to adjust the area OF aperture
- The instrument is ; - cheap, reliable, used through industry, accounting for about 20% OF all Flowmeters sold
- inaccuracy of cheapest instrument; ± 5%, but more expensive versions inaccuracy; ± 0,5%, so inaccuracy ± (0,5 - 5%)

* 16.2.3 ;- positive displacement Flowmeters :-
- account nearly 10% of total no. OF Flowmeters (مبيعات)
→ cheapest instrument inaccuracy (± 2%)
→ expensive " ; " ; ± 0,5%
So inaccuracy (± 0,5 - 2%)

- All positive displacement meters operats by using mechanical Division to displace discrete volumes of fluid successively.

* 16.2.4; Turbine meters;- consists of multi-bladed wheel mounted in apipe along an axis parallel to the direction of Fluid flow in the pipe,

The flow of Fluid past the wheel causes it to rotate at an rate that is proportional to volume flowrate of Fluid

→ inaccuracy; can be as low as ±0.2%.

- using a turbine meter calibrated on pure liq to measure a liq containting 5% air produces 50% measurement error.

- Important application of turbine meter in petrochemical industries.

* 16.2.5;- Electromagnetic flowmeters;- Limited to measuring volume flow rate of electrically conductive fluids.

→ inaccuracy; ± 1%.

- The instrument consists of stainless steel cylindrical tube fitted with an insulating liner, which carries the measured Fluid.

- Typical lining materials is used are Neoprence, polytera Flurocarbon etc. (PTFE) and polyurthane.

* A magnetic field is created in the tube by placing mains energized field coils either side of it, and the voltage induced in the fluid is measured by 2 electrodes inserted into opposite sides of the tube.

* 16.2.6 :- Vortex - Shedding flowmeters :- is relatively new type of instruments which is rapidly gaining in popularity and is being used as an alternative to traditional differential pressure in more applications.

* - The operating prinaple of the instrument is based on the natural phenomenon of vortex shedding. creating By placing an unstreamlined obstacle (known as bluff body) in a fluid carrying pipe. → Fig 16.11 جاهز

*** 16.2.7 :- Ultrasonic flowmeters :-

- Like the magnetic flowmeters, anon - intrusive methode. it is not restricted to conductive fluids, however, and is particularly useful for measuring the flow of corrosive fluids and slurries.

→ 2 - different types of Ultrasonic flowmeter :-

* ① Doppler shift Ultrasonic :-

* The prineipe of operation, A fundemental requirement of these instruments is the presence of scattering elements within the flowing fluids, which defleet the Ultrasonic energy output from the transmitter such that it enters the receiver. → Fig 16.12. جاهز

* ② Transit - time ultrasonic :- designed for measuring volume flow rate in clean Liq or gases. → Fig 16.13 جاهز

It consist of a pair of Ultrasonic transducers mounted along an axis aligned at angle θ with respect to Fluid Flow axis.

* 16.2.8 ; other types of flowmeter measuring volume flow rate ; ① gate meter

② cross - correlation flowmeter / ③ Laser Doppler flowmeter.

Ch:17

ch:17: Level measurment.

17.1; Dipsticks; ordinary dipstick is the cheapest device.

17.2; Float systems;

wherely the position of a float on the surface of a liquid is measured By means of a suitable transducer.

→ inaccuracy; ±1 %

→ This methode is; simple, cheap, widely used.

- float and tape gauge (tank gauge); Alternative of potentiometer, and it's used in greater numbers.

→ popular in many applications.

→ maintainence always high.

17.3; Pressure-measuring devices (hydrostatic-systems);

→ The Liquid Level; $h = \frac{\text{Pressure}}{\rho g} = \frac{p}{\gamma}$

$p = \gamma h = \rho g h$

→ Temp measurment may Be required If very accurate Level measuroment are needed.

→ measurment inaccuracy; varies according to the applications and the condition of the measured material,

- value would Be ± 0,5 % of Full scale reading.

also ±0.1% can Be achieved in some circumstances.

17.4; Capacitive Devices:

are widely used for measuring the level of both Liquid and solids powdered or Granular form.

- They perform well in many applications, but become inaccurate if the measured substance is prone to contamination by agents that change the dielectric constant.

→ The total capacitance is decreasing By increasing the Fluid Level, Because the material of the fluid will prevent capacitance from work.

→ If the capacitive level sensor is going to Full, then the capacitance will be equal to zero, C=0

→ If the Distance between the 2-walls of capacitive sensor increase, the capacitance will decrease.

→ Uncertainty; ±1-2 %.

17.5; Ultrasonic level Gauge:

The principle is that energy from an ultrasonic source above the Liquid is reflected back from the liq surface into an Ultrasonic energy detector.

- Ultrasonic especially useful in measuring the position of interface between 2 immiscible Liq contained in some vessel or measuring the sludge Level at the bottom of liq filled tank.

In either case the methode employed is to fix the ultrasonic transmitter-receiver transducer at a known high in upper liq, as shown in Fig 17.5 This establishes Level of Liq/Liq or liq/sludge level in absolute terms.

→ in accuracy; can be reduced to ±1%

*17.6; Radar (microwave) methods:-
an alternative technique for non-constant measurment
→ very expensive.
- The technique involves directing a constant-amplitude, frequency modulated microwave signal at the liq surface.
A receiver measure the phase difference between reflected signal and original signal.
→ Similar to Ultrasonic Level in principle.
→ Advantage: the transmission time of radar through air almost totally unaffected by ambient Temp and pressure Fluctuations.

*17.7; Radition methods:-
Is an expensive technique.
Uses a radition source & detector sys located outside a liq Filled tank in the manner.
The non invasive nature of this technique in using a source and detector sys outside the tank is particularly attractive.
- The absorption of beta and gamma rays varies with amount of liq between the source and detector, and is a Function of liq level.

* عرفت الرادارات وإكتشفها ... عشان آلية العمل بتعتمد عليها.

بالتوفيق خباب
غادة بهية

Ch: 18

Ch:18:- Mass, Force and Torque measurment.

- 18.1: mass (weight) measerment:-

Mass: Quantity of matter that a body contains.

- Load cells are most common istrument to measure mass, especially in industrial. Most load cell are now electronic, although pneumatic and hydraulic type also exist.

alternative To load cells, mass balance, instrument or spring balance.

- 18.1.1: Electronic load cell (electronic balance):-

the gravitational Force on the Body being measured is applied to an elastic element. This deflects according to the magnitude of the body mass.

- Mass measurment is thereby translated into a displacement measurment task.

Advantage:- low cost, wide measurment range, tolerance of dusty and corrosive environments, remote measurment capability, tolerance of shock loading and ease of installation.

- The electronic load cell uses the physical prinepl that a force applied to an elastic element produces a measurable deflection.

- Load cells exist in both compression and tension type.

- In compression type: the measured mass is placed on top of a platform resting on the load cell, which therefor compresses the cell.

- tension Type: mass is hung from the load cell thereby putting the cell into tension.

- Various types of displacement transducer are used to measure the deflection of the elastic elements. of these;

* Strain gauge; most commonly, Best accuracy with inaccuracy, Less than ±0.05% of Full scale.

- load cell including Strain Gauges are used to measure masses over avery wide range between (0 - 3000 tones).

* Individual instrument; measure masses range (0.1 - 5 kg.) this is bottom end of the range, and The top of the range (10 - 3000 tones).

* Elastic force transducers based on differential transformers (LVDTs) to measure deflections are used to measure masses up to 25 tones.

- Apart from having a lower max measuring capability, they are also inferior to strain gauge - based instrumens, in term of their ±0.2% inaccuracy.

* Piezoelectric device; fined type of displacement transducers used in The class of instrument,

→ measure masses in range (0 - 1000 tonnes)

- cheap, Lowest inaccuracy is ± 1% of Full scale

- have a high temp coefficient

* 18.1.2; Pneumatic / hydralic load cells;

translate mass measurment into pressure measurment tasle.

- Pneumatic load cell;

How it works?; Application of mass to the cell causes deflection of diaphragms acting as a variable restriction in a nozzle - flapper mechanism,

- The instrument requires a flow of air at it's input of around 0.25 m³/hour at pressure of 4 bar.
- Standard cell available to measure wide range of masses.
  - → For measuring small masses, instruments available with a Full-scale reading of 25 kg, and the top of the range instruments with a Full-scale of 25 tonnes.
  - → inaccuracy ±0.5% of Full scale.

- hydraulic:

How it work?: In this the gravitational force due to the unknown mass is applied via a diaphragms, to oil contained within an enclosed chamber.

- This instrument designed for measuring much larger masses than Pneumatic cells, with load capacity of 500 tonnes.
- Special units can be measure masses as large as 5000 tons.
- hydraulic cells much more accurate than Pneumatic cells with inaccuracy of: ±0.05% of Full scale.
- in order to obtain such a level of accuracy, correction for the local value of g (gravitional acceleration) is nessesary.
- A measurment resolution: 0.02%.

X 18.1.3; Intelligent Load cells:- are formed by adding a microprocessor to a standard cell. This brings no improvement in accuracy, because load cell is already a very accurate device.

X 18.1.4;- Mass - balance (weighing) instruments:- are based on comparing the gravitional force on the measured mass with the gravitional force on another Body of known mass. This principle known as weighing and used in instrument like beam balance, weigh beam, Pendulu scale, electromegnitic Balance.

(1) Beam balance (equal-arm balances) → it's world standard masses are added to a pan on one side of pivoted beam until the magnitude of the gravity force on them balances the magnitude of the gravitional force on unknown mass acting at the other one of the beam

→ this type are capable of measure a wide range of masses

- the top of range up to 1000 grams.
- the bottom less than 0.01 gram.
- measurment resolution can be good as; 1 part in 10^7 of Full scale.
- Lowest measurments inaccuracy; ± 0.02%
- Advantages:- Lack of ruggedness.

* Weigh beam:- operates on similar principles to beam balance but is much more rugged.
- Versions of these instruments are used to measure masses up to 50 tonnes

* Pendulum scale:- works on the mass-Balance principle.
- The Downward motion of the platform, and hence rotation of the cams, under the influence of the Gravitational Force on the mass, is opposed by the Gravitional force acting on 2- pendelulum type masses attached to the cams.
→ The instrument can measure masses in range (1kg — 600 tones)
→ inaccuracy; ±0.1%

* Electromagnetic Balance:
use the torque developed By a current-carrying coil suspended in a permanent magnetic field to balance the unknown mass against known gravitional force produce on a standard mass
- A Light source and Detector sys is used to determine the null balance point.
- Smaller size, its insensitivity to enviromental changes, electrical form output.

18.1.5:- Spring balance; a method both simple and cheap.
The mass is hung on end of spring and the deflection of spring due to downward gravitional force on the mass measured against scale.
→ accuracy usually poor, → inaccuracy less than ±0,2%
→ measur masses (0,5 kg — 10 tonnes).

* 18.2; Force measurment:-

F = MA; F: Force, M: mass, A: acceleration

one way of measuring unknown force is therefor to measure the acc when it applied to a body of unknown mass.

- other technique is to measure the variation in the resonat frequancy of vibrating wire as it tensioned by a force

* 18.2.1; use of accelerometers;

the technique of applying a force to a known mass and measuring the acceleration produced can be carried out using any type of accelerometer.

* 18.2.2; Vibrating wire sensor:-

The instrument consists of a wire that is kept vibrating at its resonat frequancy by a variable Frequancy oscillator

* Frequancy of a wire under tensions

$$f = \frac{0.5}{L}\sqrt{\left(\frac{M}{T}\right)}$$; L; length , T; tension

F; Fregeancy. M; mass per unit length

* 18.3; Torque measurment;-

Torque measurment is necessary part of measuring the power transmitted by rotating shafts.

3 - traditional methods of measuring Torque consists of;

(*) measuring the strain produced in rotating body due to an applied torque

* measuring reaction force in shaft. bearing

* prony brake method

*18.3.1; Reaction force in shaft Bearing si-

Any sys involving Torque transmission through a shaft contains both power source and power absorber where the power is dissipated.

- pendulum scale very commonly used for measure reaction force

*18.3.2; prony brake;-

used to measure the torque in rotating shaft and consists of a rope wound round the shaft.

one end of the rope is attached to spring balance and the other end carries load in the form of standard mass.

⟶ effective force (Fe) = mg - Fs ⟶ Force in spring balance

⟶ If R_s is radius of shaft and the rope (Rr), then.

effectiv Radius (Re) of rope and drum with respect to axis of rotation is; Re = Rs + Rr.

⟶ Torque in shaft T = Fe Re.

*18.3.3; measurment of induced Strain;-

the most common methode used for tourge measurment in recent years.

- very attractive, Because it does not disturb the measured sys by introducing friction tourges in same way as the last 2 methods.

the methode involves bending Four (4) strain gauges onto the shaft, where the strain gauges are arranged in dc bridge circuit /* it's very important that the position of strain guage on the shaft is precise. /* This methad ideal to measur stalled tourge in shaft before rotating

* 18.3.4: Optical torque measurment:-
Have Became available recently with the development of Laser diodes and Fiber optic Light transmission sys.
- Two Blacle and white striped wheels mounted at either end of the rotating shaft and are in alignment when no torque applied to shaft.
Light from laser diode Light source is Directed by a pair of optic Fiber cables onto the wheels.

→ The cost are relatively low, and in many application, his advantage is the small size.

- بالنسبة لرسمات أو أشكال ch.18 ... ستوفها وضعتها بكسرة لانه اغلب شرح مبادئ العمل يتكون عن طريق رسمات.

- مع خالص الاحترام والتقدير ... أخوكم وزميلكم نجدي دعواتكم ❤ ...